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A COMPARISON OF THE KEEPING QUALITY OF JONATHAN AND OF RED DELICIOUS APPLES STORED IN FIELD BOXES OR PREPACKAGED IN FILM BAGS

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CONTENTS

Page

Summary 1

Introduction 1

Background 2

Materials and methods 3

Results and discussion 5

  Fruit firmness 5

  Weight loss 5

  Fruit shrivelling 8

  Ground-color rating 10

  Decay 11

  Internal breakdown 12

  Jonathan spot 13

  Storage scald 13

  Soluble solids, titratable acidity, and pH of juice 13

  Repacking after storage 14

Literature cited 15

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A COMPARISON OF THE KEEPING QUALITY OF JONATHAN AND OF RED DELICIOUS APPLES STORED IN FIELD BOXES OR PREPACKAGED IN FILM BAGS

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SUMMARY

Jonathan and Red Delicious apples from each of three orchards were either stored bulk (loose) in bushel field boxes or prepacked in 4-pound perforated polyethylene film bags within corrugated shipping containers. Fruit of both varieties from these two types of containers was examined after 1, 2, and 3 months' storage at 32° and 40° F. and after an additional 7 days at 70° following storage. After storage there was little difference in firmness between apples stored in field boxes and those stored prepackaged. The largest loss in firmness was during the first month in storage. Apples softened much faster at 40° than at 32°.

Prepackaged apples stored for 3 months lost considerably less weight than bulk-stored apples. In general, shrivelling was not a problem with prepackaged apples of either variety during 3 months' storage at 32° or 40° F.; whereas, Jonathan apples stored in field boxes shrivelled appreciably, particularly after 2 and 3 months' storage plus the 7-day period at 70°. Shrivelling differences between fruit from different orchards were considerable for bulk-stored Jonathan apples. The fruit that was firmest or least mature at harvest shrivelled more than other fruit during storage and handling.

Decay was not serious with either variety when fruit was stored at 32° F. There was no indication that prepackaged apples developed more decay than bulk-stored apples during 1 to 3 months' storage. Internal breakdown also was negligible with Red Delicious apples stored up to 3 months at 32° or 40° in both prepackaged and bulk form. Internal breakdown was a major cause of deterioration in Jonathan apples, particularly those stored at 40°, in both prepackaged and bulk fruit. Most of the internal breakdown developed during holding at 70° following storage, and more developed in prepackaged fruit than in bulk fruit. The amount of internal breakdown following storage varied in different lots of fruit, but was most extensive in the fruit that was most mature at harvest.

Jonathan apples did not scald during 3 months' storage at 32° or 40° F. or during the 7-day holding period at 70° following storage. Some scald developed on the Red Delicious apples from two of the three orchards during 3 months' storage at 32°. This scald developed on both prepackaged and bulk lots even though fruit was initially treated with the scald-inhibitor ethoxyquin.

Apples in these tests showed little difference in keeping quality during short storage whether they were prepackaged or bulk stored in field boxes. Good-quality Jonathan and Red Delicious apples can be stored prepackaged in film bags in master cartons for up to 2 months at 32° F. without any repacking problem. Longer storage of fruit prepackaged at harvest would increase the risk of deterioration (decay, scald, internal breakdown) and the possible need for repacking some of the fruit. The main values of prepackaging apples before storage are reduction of injuries and costs from double handling and reduction of weight loss and shrivelling.

INTRODUCTION

Increasing quantities of apples are packaged in 3-, 4-, 5-, 8-, and 10-pound perforated film bags at production areas and in terminal markets. In 1966, about 60 percent of all apples sold on the fresh market were prepackaged, according to U.S. Department of Agriculture estimates. A common practice in production areas is to store either graded or orchard-run apples in field boxes or in pallet bins at harvest and prepackage them as orders are received. This practice gives a "fresh pack" but requires considerable handling. Bruising of apples generally is directly proportional to the amount of handling. If part of the crop could be prepackaged at harvest and stored successfully in master containers until sold, quality for consumers might be at least as good as, if not better than, that of apples in "fresh packs."

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[1] The authors are stationed at Beltsville, Md.

This study was conducted to determine how long freshly harvested, prepackaged apples could be held satisfactorily in refrigerated storage. The keeping quality (physical and chemical condition) of eastern-grown Jonathan and Red Delicious apples bulk stored in bushel field boxes or prepackaged in 4-pound perforated polyethylene film bags within corrugated shipping containers was compared, and the extent of deterioration over a 3-month storage period was determined.

BACKGROUND

Consumer packaging or prepackaging fresh produce developed along with the growth of the supermarket in the United States. Prepackaging apples and other produce was necessary if produce departments were to become self-service, as other departments. Claimed advantages of prepackaging, in addition to the advantage of self-service, are that prepackaging is a good way to market small apples, that it increases sales, that it gives a higher net return, and that it reduces weight loss and bruising. A review of literature on the growth of prepackaging and on produce packaging requirements for apples has been published (19).[2]

Apples are packaged for the consumer in production areas, in central warehouses, in terminal markets, and in retail stores. Carlsen and Stokes (1) found that it was economically feasible to prepackage high-quality apples in production areas if costs of packaging materials were kept at a minimum. To develop efficient procedures, several investigators have studied methods and equipment for packaging apples (1, 5, 10, 13). Dominick (4) and Merchant, Underwood, and McDonald (12), in studies with McIntosh apples, showed that sales were highest when both bulk and prepackaged apples were displayed together in retail stores. Havas and others (8), on the other hand, found that when apples of premium quality and size were prepackaged in sleeve-wrapped trays, overwrapped trays, open trays, or polyethylene bags, total sales were about the same, whether the fruit was displayed in packages only or in both packages and bulk.

The polyethylene bag continues to be the standard package for apples, especially for the smaller sizes. Standard thickness or gage of film is 1.25 or 1.5 mils (0.00125 or 0.0015 inch). Various other consumer packages have been tested because of reports of excessive bruising in jumble-packed film bags (2, 3, 5, 8, 9, 11, 12, 15). For a tender variety like McIntosh, over-wrapped trays and trays or cartons with cells or dividers provide more protection against bruising and stem punctures during shipping and retailing than film bags provide (2, 3, 9, 11, 12, 15). However, packaging costs are higher for trays and cell cartons than for film bags (5, 8, 9, 15). Shrinkable film overwraps for tray-packed apples are useful to immobilize fruit and thereby reduce contact bruising (2, 5, 9).

Perkins (14) studied the extent of bruising of apples in polyethylene bags during shipment to market and found that the method of placing bags within master containers was important. Apples were more bruised when the bags were packed vertically than when they were packed horizontally in the master container. Fountain (5) evaluated several types of pads placed between layers of prepackaged apples in master containers. He concluded that none of the packs provided as much protection against bruising as effectively as rigid separators that prevented the layers above from touching the layers below.

Havas and others (8) reported that weight losses and decay during retailing were generally higher when prepackaged apples were displayed on nonrefrigerated counters than in refrigerated display cases.

The physiological effects of packaging apples within transparent film containers have been investigated extensively. Usually perforated bags or overwraps are recommended to provide ventilation for the apples during storage and marketing (6, 7, 16, 17, 18). Hardenburg, Schomer, and Lieberman (7) showed that perforating a consumer package with two ¼-inch holes usually would keep the atmosphere surrounding the apples near normal and would avoid possible injury from suboxidation or accumulated carbon dioxide. However, more perforations are recommended to prevent the relative humidity from approaching saturation at warm temperatures, which might increase growth of surface mold and decay and promote fogging (6). Sixteen or more ¼-inch holes are suggested for 3- to 5-pound polyethylene bags. Scott and Tewfik (17) showed that when Gallia Beauty apples were packaged in several types of nonperforated films, carbon dioxide accumulated to 14 to 30 percent and oxygen was depleted to 0.3 to 5.6 percent within 5 days at 72° F. Such abnormal atmospheres would eventually have deleterious effects on fruit quality.

Tomkins (18) studied the conditions produced in film packages by fresh fruits and vegetables and the effect of these conditions on storage life. When six apples were sealed in one type of 1.5-mil polyethylene, the higher the storage temperature the higher the concentration of carbon dioxide that accumulated. For example, at 32° F. the equilibrium concentration of carbon dioxide averaged 5 percent; at 50°, about 10 percent; and at 68°, about 15 percent. Thus, the chance that product respiration will cause injurious concentrations of carbon dioxide to develop within sealed packages is much greater at warm temperatures than when the product is refrigerated. Similarly, injury may be caused by excess depletion of oxygen within sealed packages.

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[2] Underscored numbers in parentheses refer to Literature Cited at the end of this report.

Ritter and Thomas (16) stored Pennsylvania-grown Stayman and Rome Beauty apples at 35° F. in perforated and nonperforated 5-pound polyethylene bags and in bulk after harvest, and then examined fruit texture and flavor in January. They concluded that apples prepackaged at harvest kept as well as apples bulk stored for up to 10 weeks. Stayman apples stored in nonperforated bags had a less acceptable flavor than fruit stored in perforated bags (16).

MATERIALS AND METHODS

The study was conducted in the fall and winter months of 1961-62 in experimental cold storage rooms at Beltsville, Md. The storage rooms were of half-car capacity, and were cooled with Freon as the primary refrigerant and ethylene glycol, the direct refrigerant, circulated through blower coil units in each room. Each room had an activated charcoal air-purifying unit. The Jonathan and Red Delicious apples tested were freshly harvested from three commercial orchards—two in West Virginia and one in Virginia. Harvest dates for the Jonathan apples were: September 28 (orchard A), September 21 (orchard B), and September 24 (orchard C). Harvest dates for the Red Delicious apples were September 30 (orchards A and B) and September 28 (orchard C). All the Delicious apples were dipped in ethoxyquin ("Stop Scald") before storage for protection from scald. The apples were U.S. No. 1 grade and 2¼-inch minimum diameter size.

Before storage, half the apples from each orchard were prepackaged in 4-pound polyethylene bags (1.5 mil gage), and half were bulk stored in bushel field boxes. All the polyethylene bags were perforated with ¼-inch holes to provide ventilation. The number of perforations per bag varied with different packers as follows: 24 for orchard A, 32 for orchard B, and 40 for orchard C. After prepackaging, the bagged apples were stored in master corrugated cartons. Each carton contained twelve 4-pound bags (fig. 1).

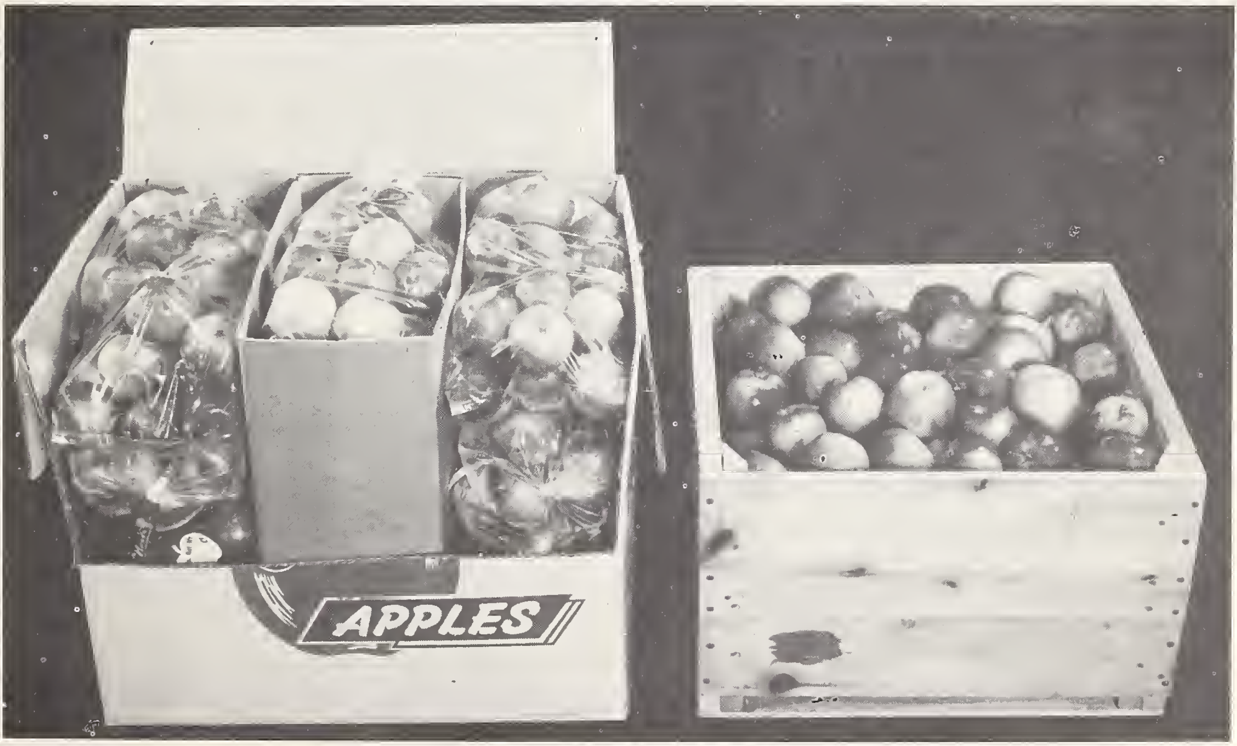

Figure 1.—Master carton with cut-away side to show apples prepackaged in polyethylene bags *(left)*, and field box of bulk apples *(right)*.

Half the fruit was stored at 32° F. and half at 40° for comparison of keeping quality over a 3-month period. These storage rooms maintained the assigned temperature within ±1°. Relative humidity in rooms ranged from 80 to 85 percent, but it averaged slightly lower in the 32° room than in the 40° room. A relative humidity of 90 percent would have been better to minimize moisture loss. Three corrugated boxes of prepackaged apples and three wood field boxes of bulk apples from each orchard and of each variety were stored at each temperature. One box of each storage type at each temperature and from each orchard was removed at monthly intervals and evaluated for condition. A summary of the experimental outline and the quantities of fruit stored for later examination is given in table 1.

Following the examination on removal from storage, some of the fruit was held 7 days at 70° F. to simulate a marketing period without refrigeration and then was reexamined. The relative humidity in the 70° room was maintained at 50 percent. After storage some fruit was also placed in an open-top, mechanically refrigerated display case. However, the case did not operate properly so these results are not presented.

The examination after storage determined firmness, weight losses, extent of shrivelling, ground color, decay, internal breakdown, and physiological disorders such as Jonathan Spot and storage scald. Extracted juice was analyzed for soluble solids, titratable acidity (calculated as malic acid), and pH.

Table 1.—Descriptive summary of apple storage experiments with each variety

Item	Prepackaged apples (twelve 4-lb. bags/box) from orchard-			Bulk apples (approximately 1 bu./box) from orchard-		
	A	B	C	A	B	C
	Number	Number	Number	Number	Number	Number
Total boxes stored	6	6	6	6	6	6
Boxes stored at 32° F.	3	3	3	3	3	3
Boxes stored at 40° F.	3	3	3	3	3	3
Boxes removed each month from 32° F	1	1	1	1	1	1
Boxes removed each month from 40° F	1	1	1	1	1	1
Bags examined each month from each temperature	4	4	4	-	-	-
Bags examined each month plus 7 days at 70° F.	4	4	4	-	-	-
Boxes examined each month from each temperature	-	-	-	1	1	1
Boxes examined each month plus 7 days at 70° F.	-	-	-	1/2	1/2	1/2
Apples pressure tested at each examination	20	20	20	20	20	20
Number of firmness readings at each examination	40	40	40	40	40	40
Apples sampled for chemical analysis at each examination	20	20	20	20	20	20

In determining firmness, a Magness-Taylor pressure tester with 7/16-inch plunger was used on a 20-fruit sample selected at random from each treatment. Five apples from each of four 4-pound bags made up the sample for the prepacked apples. Pressure tests for firmness were made on two opposite sides of each apple, giving 40 readings from which averages were determined. Ground color was visually rated on the same 20 apples, using a 1 to 4 scale (1 = green, 4 = yellow or all red). A segment of each half of each of the 20 apples was then cut, combined, ground, filtered and centrifuged. The resulting juice was analyzed for soluble solids, titratable acidity, and pH.

RESULTS AND DISCUSSION

Fruit Firmness

The initial firmness of commercially harvested apples differed appreciably among the three orchards sampled. Initial firmness of the Jonathan apples was 16.8, 17.3, and 15.0 pounds, for orchards A, B, and C, respectively. Initial firmness of the Delicious apples varied even more and was 12.5, 17.1, and 15.6 pounds for orchards A, B, and C, respectively. Firmness at harvest is an important factor related to the storage potential of apples.

Fruit firmness for the prepackaged and bulk-stored apples after 1, 2, and 3 months' storage at 32° and 40° F. is shown in table 2. As expected, apples softened much faster at 40° than at 32° in most instances. This was true for both prepackaged and bulk apples. After 3 months' storage at 32° the Jonathan apples averaged 1.1 and 2.3 pounds firmer for prepackaged and bulk apples, respectively, than for similarly packaged apples stored at 40°. Similar differences in favor of 32° storage were found with the Delicious variety. In 15 of 18 comparisons, the mean firmness of the bulk Delicious apples was slightly higher than firmness of the prepackaged apples. The bulk Jonathan apples averaged 0.3 pound firmer than the prepackaged apples. The bulk Delicious apples averaged 0.7 pound firmer than the prepackaged apples after storage (table 2). These slight differences in firmness probably are of little, if any, practical significance because the bulk apples lost more weight in storage. The largest loss in firmness was during the first month in storage, after which the rate of softening was slower. In several instances, fruit was slightly firmer after 3 months' storage than after 1 months' storage. This may be due to toughening of fruit texture due to weight loss, as well as to experimental sampling errors.

Fruit firmness decreased still further during a simulated marketing period of 7 days at 70° F. following storage. Loss in firmness during the 7 days at 70° averaged 1.4 pounds for the prepackaged apples and 1.7 pounds for the bulk apples.

Weight Loss

Apples stored 1, 2, and 3 months prepackaged in polyethylene bags within corrugated shipping containers lost considerably less weight than apples bulk stored in wooden field boxes (table 3) (fig. 2). After 3 months at 32° F., weight losses of Jonathan apples averaged 1.6 percent for prepackaged apples and 3.5 percent for bulk apples. Weight losses for Delicious apples after the same storage period were 1.5 percent for prepackaged apples and 2.6 percent for bulk apples.

Weight losses approximately doubled when apples were held 7 days at 70° F. with 50 percent relative humidity after 1, 2, and 3 months' storage. For example, data in table 3 show that average weight losses of bulk stored Delicious apples were 1.2, 2.1, and 2.6 percent after 1, 2, and 3 months, respectively, at 32°. When these apples were held an additional 7 days at 70° following 1, 2, and 3 months at 32°, average weight losses increased to 2.4, 4.1, and 5.2 percent, respectively.

Weight losses during storage at 40° F. were not appreciably higher than at 32° in these tests with prepackaged and bulk apples.

The number of ventilation holes in the 4-pound bags—whether 24, 32, or 40 one-quarter inch holes—made little difference in weight loss when bags were stored within corrugated shipping containers.

Table 2.—Firmness of prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.[1]

Variety and storage period	Firmness with Magness-Taylor pressure tester							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Jonathan (after storage):								
1 month 32° F.	14.5	14.3	11.0	13.3	14.3	13.3	12.5	13.4
2 months 32° F.	12.7	13.3	12.1	12.7	13.6	13.9	12.4	13.3
3 months 32° F.	11.2	11.7	11.7	11.5	11.6	12.5	13.9	12.7
1 month 40° F.	10.8	11.4	10.8	11.0	11.7	10.7	9.1	10.5
2 months 40° F.	11.6	11.5	11.4	11.5	11.8	12.2	11.2	11.7
3 months 40° F.	9.9	10.8	10.6	10.4	10.3	10.9	10.0	10.4
Jonathan (after storage plus 7 days at 70° F.):								
1 month 32° F.	10.2	10.7	9.6	10.2	10.1	10.5	10.2	10.3
2 months 32° F.	10.9	11.1	10.5	10.8	10.8	10.7	11.3	10.9
3 months 32° F.	9.9	10.1	9.3	9.8	9.8	10.4	9.9	10.0
1 month 40° F.	8.9	9.9	9.3	9.4	9.6	9.9	9.1	9.5
2 months 40° F.	11.0	10.3	10.1	10.5	10.9	11.5	10.4	10.9
3 months 40° F.	9.2	9.7	9.5	9.5	9.0	9.8	9.1	9.3
Delicious (after storage):								
1 month 32° F.	11.0	16.1	13.2	13.4	10.5	18.3	15.3	14.7
2 months 32° F.	11.2	16.3	13.2	13.6	11.6	16.6	13.9	14.0
3 months 32° F.	11.9	15.7	14.1	13.9	12.3	17.3	14.4	14.7
1 month 40° F.	9.0	13.3	10.5	10.9	8.1	12.5	12.5	11.0
2 months 40° F.	9.0	11.3	10.6	10.3	10.1	12.3	11.5	11.3
3 months 40° F.	10.2	12.0	11.3	11.2	10.9	12.5	12.2	11.9
Delicious (after storage plus 7 days at 70° F.):								
1 month 32° F.	9.4	12.2	12.4	11.3	9.9	13.8	11.3	11.7
2 months 32° F.	9.0	13.2	11.4	11.2	10.3	14.5	12.5	12.4
3 months 32° F.	10.1	14.6	14.2	13.0	10.2	14.4	12.1	12.2
1 month 40° F.	8.8	11.9	11.1	10.6	10.1	13.3	12.0	11.8
2 months 40° F.	8.5	9.9	9.8	9.4	8.9	11.3	11.2	10.5
3 months 40° F.	9.4	12.6	11.8	11.3	8.5	9.9	12.6	10.3

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[1] Firmness at harvest for Jonathan apples from orchards A, B, and C, was 16.8, 17.3, and 15.0 pounds, respectively. Firmness at harvest for Delicious apples from orchards A, B, and C, was 12.5, 17.1, and 15.6 pounds, respectively.

Table 3.–Weight loss of prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.

Variety and storage period	Weight losses of apples							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Jonathan (after storage):								
1 month 32° F.	0.5	0.5	0.5	0.5	1.7	1.4	1.7	1.6
2 months 32° F.	1.0	.9	1.0	1.0	4.4	2.5	2.2	3.0
3 months 32° F.	1.5	1.7	1.6	1.6	3.5	3.7	3.3	3.5
1 month 40° F.	.4	.5	.4	.4	1.4	1.1	1.3	1.3
2 months 40° F.	.7	.6	.8	.7	1.9	2.5	1.7	2.0
3 months 40° F.	1.1	1.1	1.1	1.1	5.6	3.3	2.5	3.8
Jonathan (after storage plus 7 days at 70° F.):								
1 month 32° F.	1.8	2.6	1.9	2.1	3.7	3.7	3.9	3.8
2 months 32° F.	2.5	2.2	2.9	2.5	6.6	4.0	4.4	5.0
3 months 32° F.	3.0	3.8	3.3	3.4	5.8	8.0	5.4	6.4
1 month 40° F.	2.1	2.3	2.2	2.2	2.8	3.4	3.1	3.1
2 months 40° F.	2.2	1.9	2.3	2.1	3.4	4.4	2.4	3.4
3 months 40° F.	2.8	3.3	2.9	3.0	8.5	5.1	4.1	5.9
Delicious (after storage):								
1 month 32° F.	.4	.6	.6	.5	1.2	1.5	.8	1.2
2 months 32° F.	.8	.9	1.1	.9	1.8	2.7	1.7	2.1
3 months 32° F.	1.2	1.8	1.6	1.5	2.0	3.6	2.3	2.6
1 month 40° F.	.5	.5	.6	.5	1.2	1.5	1.1	1.3
2 months 40° F.	.7	1.1	1.1	1.0	2.0	2.9	2.6	2.5
3 months 40° F.	.9	1.2	1.6	1.0	2.9	4.3	2.9	3.4
Delicious (after storage plus 7 days at 70° F.):								
1 month 32° F.	1.6	2.2	1.9	1.9	1.9	3.0	2.2	2.4
2 months 32° F.	2.2	3.0	2.4	2.5	3.2	4.9	4.2	4.1
3 months 32° F.	2.6	3.7	3.0	3.1	5.0	6.4	4.3	5.2
1 month 40° F.	1.6	1.9	1.8	1.8	3.3	3.0	2.4	2.9
2 months 40° F.	2.1	2.7	2.3	2.4	4.1	5.1	4.7	4.6
3 months 40° F.	2.3	2.9	2.6	2.6	5.8	5.8	5.0	5.5

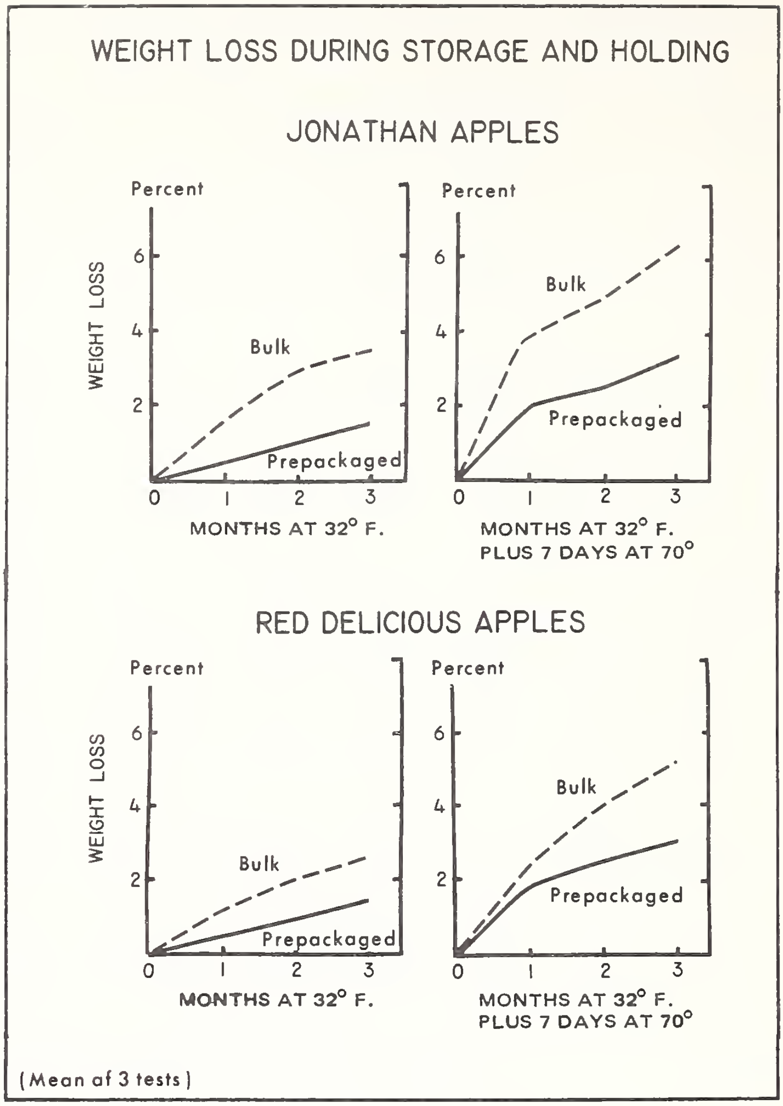

Figure 2.—Weight losses of prepackaged and bulk Jonathan and Red Delicious apples after storage for 1, 2, and 3 months at 32° F., and after an additional 7 days at 70°.

Fruit Shrivelling

In general, shrivelling was not a problem with prepackaged apples of either variety during 3 months' storage at 32° or 40° F. Jonathan and Delicious apples prepackaged in 4-pound polyethylene bags showed negligible shrivelling from moisture loss after 1, 2, or 3 months' storage at 32° F. or at 40°. After 3 months' storage at 32° plus 7 days at 70°, there was still no visible shrivelling in the prepackaged Delicious apples and an average of only 3.4 percent shrivelling in the prepackaged Jonathan apples stored at 32° (table 4).

Table 4.–Shrivelling of prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.

Variety and storage period	Shrivelled apples							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Jonathan (after storage):								
1 month 32° F.	0	0	0	0	0	2.4	1.3	1.2
2 months 32° F.	0	0	0	0	5.2	22.1	4.6	10.6
3 months 32° F.	1.5	0	0	.5	1.6	30.0	7.2	12.9
1 month 40° F.	0	0	0	0	0	0	0	0
2 months 40° F.	0	0	0	0	.8	4.6	0	1.8
3 months 40° F.	0	0	0	0	0	2.4	0	.8
Jonathan (after storage plus 7 days at 70° F.):								
1 month 32° F.	0	1.8	0	.6	3.3	10.6	4.9	6.3
2 months 32° F.	0	0	0	0	5.5	25.0	3.3	11.3
3 months 32° F.	0	8.5	1.6	3.4	4.0	51.0	26.6	27.2
1 month 40° F.	0	0	0	0	1.8	12.8	1.6	5.4
2 months 40° F.	0	0	0	0	0	19.1	0	6.4
3 months 40° F.	0	0	0	0	12.5	36.4	15.2	21.4
Delicious (after storage):								
1 month 32° F.	0	0	0	0	0	0	.7	.2
2 months 32° F.	0	0	0	0	0	0	1.5	.5
3 months 32° F.	0	0	0	0	0	.7	1.5	.7
1 month 40° F.	0	0	0	0	0	0	0	0
2 months 40° F.	0	0	0	0	0	0	.7	.2
3 months 40° F.	0	0	0	0	0	0	.8	.3
Delicious (after storage plus 7 days at 70° F.):								
1 month 32° F.	0	0	0	0	0	0	0	0
2 months 32° F.	0	0	0	0	0	3.4	1.7	1.7
3 months 32° F.	0	0	0	0	0	0	1.8	.6
1 month 40° F	0	0	0	0	0	0	1.8	.6
2 months 40° F	0	0	0	0	0	3.6	1.6	1.7
3 months 40° F	0	0	0	0	0	0	0	0

With bulk-stored apples, the Jonathan variety shrivelled sooner than the Delicious variety and had a higher percentage of shrivelled fruit at all the examination periods. The Jonathan variety shrivelled appreciably during 2 months at either 32° or 40° F. After 3 months at 32° plus 7 days at 70°, Jonathan apples from the 3 orchards had an average of 27 percent shrivelled fruit (table 4). Differences among orchards in extent of shrivelling for Jonathan apples were considerable. During storage or holding, fruit that was firmest at harvest and had the lowest (greenest) ground-color rating shrivelled more than softer fruit.

Ground-Color Rating

Visual subjective ratings for ground color of the two varieties after storage for various intervals are given in table 5. There were no appreciable differences in rate of ripening, as indicated by ground color, between the prepackaged and bulk-stored apples during storage at either 32° or 40° F. If the film bags had been sealed and not perforated, fruit ripening might have been retarded by the modified atmosphere resulting from respiration. However, nonperforated consumer bags are not recommended either for storage or marketing of apples because of possible harmful effects on flavor and extent of decay.

Table 5.—Ground-color rating of prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.[1]

Variety and storage period	Ground-color rating of apples							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
Jonathan (after storage):								
1 month 32° F.	3.3	1.7	3.0	2.7	3.6	1.9	3.8	3.1
2 months 32° F.	3.8	2.1	3.1	3.0	3.8	1.9	3.7	3.1
3 months 32° F.	3.7	3.2	3.7	3.5	3.9	2.3	3.8	3.3
1 month 40° F.	3.4	2.4	3.4	3.1	3.9	1.8	3.9	3.2
2 months 40° F.	3.9	3.5	3.9	3.8	3.8	2.5	3.8	3.4
3 months 40° F.	3.4	3.3	3.8	3.5	3.9	3.5	3.8	3.7
Jonathan (after storage plus 7 days at 70° F.):								
1 month 32° F.	3.8	2.7	3.7	3.4	3.8	3.6	3.9	3.8
2 months 32° F.	3.7	3.5	3.7	3.6	3.7	3.5	3.8	3.7
3 months 32° F.	3.7	3.4	3.8	3.6	3.8	3.7	3.9	3.8
1 month 40° F.	3.7	3.0	3.9	3.5	3.6	3.0	4.0	3.5
2 months 40° F.	3.7	3.4	3.9	3.7	3.6	3.4	3.9	3.6
3 months 40° F.	3.7	3.1	3.9	3.6	3.8	3.6	3.9	3.8
Delicious (after storage):								
1 month 32° F.	3.8	3.1	2.9	3.3	3.6	3.0	2.4	3.0
2 months 32° F.	3.9	3.3	3.2	3.5	3.7	3.7	3.9	3.8
3 months 32° F.	3.7	3.5	3.2	3.5	3.8	3.7	3.5	3.7
1 month 40° F.	3.7	3.1	3.0	3.3	3.6	2.7	2.8	3.0
2 months 40° F.	3.9	3.7	3.4	3.7	3.9	3.7	3.6	3.7
3 months 40° F.	3.8	3.7	3.4	3.6	4.0	3.7	3.8	3.8
Delicious (after storage plus 7 days at 70° F.):								
1 month 32° F.	3.5	3.2	3.1	3.3	4.0	3.6	3.2	3.6
2 months 32° F.	4.0	3.9	3.6	3.8	3.9	3.6	3.5	3.7
3 months 32° F.	4.0	3.8	3.5	3.8	3.9	3.5	3.6	3.7
1 month 40° F.	4.0	3.9	3.4	3.8	3.8	3.2	3.2	3.4
2 months 40° F.	3.9	3.8	3.4	3.7	4.0	3.9	3.5	3.8
3 months 40° F.	4.0	3.8	3.6	3.8	3.9	3.8	3.5	3.7

[1] Ground-color ratings at harvest for Jonathan apples from orchards A, B, and C, were 2.9, 1.8, and 3.2, respectively. Ground-color ratings at harvest for Delicious apples from orchards A, B, and C, were 3.4, 2.1, and 2.4, respectively. On the 1 to 4 rating cards used, 1 = green and 4 = yellow (or all red if no ground color is showing).

Decay

Decay was not a serious problem with either variety when fruit was stored at 32° F. Delicious apples developed slightly less decay than Jonathan apples in these storage tests (table 6). Bulk-stored Jonathan apples developed 3.4 percent decay during 2 months' storage at 40° and 4.6 percent during 3 months. There was no indication from the data that prepackaged apples develop more decay during 1 to 3 months' storage than bulk apples. However, even slight decay in prepackaged apples might affect sales and necessitate repacking as discussed in another section.

Table 6.—Extent of decay in prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.

Variety and storage period	Decay of apples							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Jonathan (after storage):								
1 month 32° F.	0	2.4	0	0.8	0	0	0	0
2 months 32° F.	0	0	0	0	0	.8	0	.3
3 months 32° F.	0	5.2	0	1.7	0	1.7	0	.6
1 month 40° F.	0	0	0	0	.7	0	0	.2
2 months 40° F.	0	0	0	0	3.3	7.0	0	3.4
3 months 40° F.	0	1.7	3.3	1.7	4.2	9.5	0	4.6
Jonathan (after storage plus 7 days at 70° F.):								
1 month 32° F.	0	1.8	0	.6	3.3	0	0	1.1
2 months 32° F.	0	0	0	0	1.8	5.8	1.7	3.1
3 months 32° F.	0	1.7	0	.6	0	0	0	0
1 month 40° F.	0	3.4	3.4	2.3	0	2.1	0	.7
2 months 40° F.	0	5.2	0	1.7	2.2	2.1	1.9	2.1
3 months 40° F.	0	1.7	0	.6	0	0	2.2	.7
Delicious (after storage):								
1 month 32° F.	0	0	1.7	.6	0	.7	0	.2
2 months 32° F.	0	0	0	0	0	0	0	0
3 months 32° F.	0	0	0	0	0	0	0	0
1 month 40° F.	0	0	0	0	0	0	0	0
2 months 40° F.	0	0	0	0	.7	0	0	.2
3 months 40° F.	1.4	0	0	.5	0	.8	0	.3
Delicious (after storage plus 7 days at 70° F.):								
1 month 32° F.	1.5	0	1.6	1.0	0	0	0	0
2 months 32° F.	0	0	0	0	0	0	1.7	.6
3 months 32° F.	4.5	0	0	1.5	0	0	0	0
1 month 40° F.	1.4	0	0	.5	0	0	0	0
2 months 40° F.	0	0	3.3	1.1	1.7	3.6	0	1.8
3 months 40° F.	0	0	1.7	.6	5.2	0	0	1.7

Internal Breakdown

Internal breakdown was not a problem with either prepackaged or bulk-stored Red Delicious apples stored up to 3 months at 32° or 40° F. In contrast, internal breakdown was a major cause of deterioration for the Jonathan apples, particularly for those stored at 40°, but it developed in both prepackaged and bulk fruit (table 7). Most of the internal breakdown developed during the 7-day holding period at 70° following storage. During that holding period, more breakdown developed in the polyethylene-bagged Jonathan apples than in the bulk-stored apples.

The extent of internal breakdown following storage was markedly different in different lots of apples, as might be expected. The Jonathan apples from orchard C, which were the softest at harvest (15 pounds), developed considerably more internal breakdown than those from the other two orchards, which were firmer apples at harvest (16.8 and 17.3 pounds). Jonathan apples from orchard C stored in polyethylene bags had 7.0 percent internal breakdown after 3 months at 32° F. and 11.5 percent after 3 months at 40°. There was no internal breakdown in the prepackaged fruit from the other two orchards after 3 months' storage.

Table 7.–Internal breakdown of prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.

Variety and storage period	Internal breakdown of apples							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Jonathan (after storage):								
1 month 32° F.	0	0	0	0	0	0	0	0
2 months 32° F.	0	0	0	0	0	0	.7	.2
3 months 32° F.	0	0	7.0	2.3	.8	0	0	.3
1 month 40° F.	0	0	1.6	.5	0	0	0	0
2 months 40° F.	0	0	3.2	1.1	0	0	3.1	1.0
3 months 40° F.	0	0	11.5	3.8	0	2.4	3.6	2.0
Jonathan (after storage plus 7 days at 70° F.):								
1 month 32° F.	5.8	5.3	10.3	7.1	0	0	1.6	.5
2 months 32° F.	4.5	5.4	16.3	8.7	1.8	3.8	0	1.9
3 months 32° F.	4.3	0	12.9	5.7	4.0	2.0	1.6	2.5
1 month 40° F.	10.1	5.1	23.7	13.0	3.6	2.1	1.6	2.4
2 months 40° F.	8.6	5.2	18.9	10.9	4.4	0	13.5	6.0
3 months 40° F.	2.7	0	26.4	9.7	0	0	8.7	2.9
Delicious (after storage):								
1 month 32° F.	0	0	0	0	0	0	0	0
2 months 32° F.	0	0	0	0	0	0	0	0
3 months 32° F.	0	0	0	0	0	0	0	0
1 month 40° F.	0	0	0	0	0	0	0	0
2 months 40° F.	1.5	1.5	0	1.0	0	.8	0	.3
3 months 40° F.	1.5	0	0	.5	1.4	0	0	.5
Delicious (after storage plus 7 days at 70° F.):								
1 month 32° F.	0	0	0	0	0	0	0	0
2 months 32° F.	2.9	0	0	1.0	0	0	0	0
3 months 32° F.	0	0	1.6	.5	0	0	0	0
1 month 40° F.	0	1.5	3.3	1.6	0	0	0	0
2 months 40° F.	3.1	1.5	0	1.5	0	0	0	0
3 months 40° F.	1.5	1.4	0	1.0	1.7	0	0	.6

Jonathan Spot

The physiological disorder known as Jonathan spot was found only on the Jonathan apples. Susceptibility to Jonathan spot varied in fruit from different orchards, and fruit of more advanced ripeness (softer) seemed more susceptible than less ripe (firmer) fruit. In these tests, Jonathan spot was approximately the same on all apples (table 8). Also, there was no apparent difference in the extent of Jonathan spot on apples stored at 32° or 40° F. for as long as 3 months.

Table 8.–Jonathan spot on prepackaged and bulk Jonathan apples after storage at 32° and 40° F.[1]

Storage period	Jonathan spot on apples	
	Prepackaged in bags	Bulk in field boxes
	Percent	Percent
After storage:		
1 month 32° F.	1.5	3.1
2 months 32° F.	4.8	3.2
3 months 32° F.	.5	2.4
1 month 40° F.	2.8	2.9
2 months 40° F.	2.5	2.6
3 months 40° F.	.5	4.4
After storage plus 7 days at 70° F.:		
1 month 32° F.	2.9	0
2 months 32° F.	3.2	1.2
3 months 32° F.	1.0	0
1 month 40° F.	2.6	0
2 months 40° F.	2.1	2.2
3 months 40° F.	1.0	.6

[1] Data are means from 3 orchards.

Storage Scald

The Jonathan apples did not scald during 3 months' storage at 32° or 40° F. or during the 7-day holding period at 70° after storage. This was true for both the prepackaged and the bulk-stored fruit.

A trace of scald developed on the Delicious variety during 3 months' storage at 32° F. on fruit from two of the orchards and on both prepackaged and bulk apples. All the Delicious apples had been treated with ethoxyquin (Stop-Scald) before storage. Additional scald developed during the 7-day holding period at 70° following 3 months' storage at 32° (table 9). Some scald also developed during holding following 2 months' storage at 32°. In general, Delicious apples stored in film bags developed no more scald and usually less scald than bulk-stored apples in field boxes. Also, apples stored at 32° developed more scald than those stored at 40°.

Scald development following storage was related to the initial maturity of the fruit as indicated by firmness and ground-color ratings. The less mature fruit scalded most. Apples that were softest at harvest (12.5 pounds) and most mature developed negligible scald during 3 months' storage at 32° F. plus 7 days at 70°.

Soluble Solids, Titratable Acidity, and pH of Juice

No consistent differences in soluble solids, titratable acidity (expressed as malic acid), or the pH of the juice were found between prepackaged and bulk-stored apples during these tests (table 10). However, there were

Table 9.–Scald on prepackaged and bulk Delicious apples after storage at 32° and 40° F.

Storage period	Storage scald of apples							
	Prepackaged in bags, from orchard-				Bulk in field boxes, from orchard-			
	A	B	C	Mean	A	B	C	Mean
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
After storage:								
1 month 32° F.	0	0	0	0	0	0	0	0
2 months 32° F.	0	0	0	0	0	0	0	0
3 months 32° F.	0	6.0	6.6	4.2	0	2.1	4.5	2.2
1 month 40° F.	0	0	0	0	0	0	0	0
2 months 40° F.	0	0	0	0	0	0	0	0
3 months 40° F.	0	0	4.4	1.5	0	4.5	10.8	5.1
After storage plus 7 days at 70° F.:								
1 month 32° F.	0	0	0	0	0	0	0	0
2 months 32° F.	0	5.8	33.9	13.2	1.7	40.7	31.0	24.5
3 months 32° F.	0	8.8	41.9	16.9	0	52.5	23.2	25.2
1 month 40° F.	0	0	0	0	0	0	0	0
2 months 40° F.	0	0	1.7	.6	0	0	4.9	1.6
3 months 40° F.	0	1.4	10.3	3.9	0	25.5	31.5	19.0

differences in these analyses between the Jonathan and Delicious varieties. Length of storage did not materially affect the soluble solids or pH of the juice, but the acid content decreased during storage. The acid content appeared to be related to fruit firmness. As stored fruit ripens and firmness declines, the acidity also declines.

Table 10.—Soluble solids, titratable acidity, and pH of juice of prepackaged and bulk Jonathan and Delicious apples after storage at 32° and 40° F.[1]

Variety and storage period	Soluble solids of apples		Titratable acidity of apples[2]		pH of juice of apples	
	Prepackaged	Bulk	Prepackaged	Bulk	Prepackaged	Bulk
Jonathan (after storage):	Percent	Percent	Percent	Percent		
1 month 32° F.	14.0	13.8	0.67	0.68	3.30	3.39
2 months 32° F.	13.8	13.8	.58	.60	3.03	3.04
3 months 32° F.	14.1	13.8	.55	.58	3.26	3.16
1 month 40° F.	14.1	13.7	.64	.62	3.23	3.38
2 months 40° F.	14.0	13.2	.55	.58	3.12	3.14
3 months 40° F.	13.7	14.0	.53	.51	3.28	3.19
Jonathan (after storage plus 7 days at 70° F.):						
1 month 32° F.	11.9	12.9	.58	.61	3.18	3.15
2 months 32° F.	13.5	13.5	.52	.57	3.18	3.17
3 months 32° F.	13.0	14.8	.48	.51	3.22	3.25
1 month 40° F.	13.0	12.8	.60	.58	3.11	3.16
2 months 40° F.	13.1	13.1	.49	.52	3.07	3.03
3 months 40° F.	13.4	13.6	.49	.52	3.21	3.22
Delicious (after storage):						
1 month 32° F.	11.6	12.3	.80	.88	3.66	3.72
2 months 32° F.	–	–	–	–	–	–
3 months 32° F.	12.6	13.3	.69	.76	3.64	3.82
1 month 40° F.	12.1	12.2	.83	.82	3.65	3.68
2 months 40° F.	–	–	–	–	–	–
3 months 40° F.	12.1	12.8	.66	.72	3.62	3.62
Delicious (after storage plus 7 days at 70° F.):						
1 month 32° F.	11.6	12.6	.81	.72	3.60	3.61
2 months 32° F.	–	–	.75	.79	3.59	3.81
3 months 32° F.	12.5	13.6	.66	.69	3.90	3.90
1 month 40° F.	12.0	12.4	.82	.75	3.50	3.64
2 months 40° F.	–	–	.74	.78	3.91	3.92
3 months 40° F.	12.4	12.9	.65	.68	3.86	3.83

[1] Data are means from 3 orchards.

[2] Titratable acidity calculated as malic acid.

Repacking After Storage

The extent of deterioration of prepackaged apples is a major consideration determining commercial practicality of packaging before storage. If apples in the transparent bags show spoilage, repacking or price markdown would be necessary for marketing. A fresh-appearing pack containing good-quality fruit is essential for continued sales.

These tests showed that there was little difference in keeping quality between prepackaged or bulk-stored apples. Based on total fruit stored, the percentage of salable apples was greater for the prepackaged apples than for the bulk apples because of less shrivelling in the bags. However, if even one or two apples in a bag developed decay or internal breakdown, the unit would be unsalable and would require repacking. Table 11 shows the percentage of the bags that contained one or more apples with decay or internal breakdown after 1, 2, and 3 months' storage and would require repacking. The data suggest that both Jonathan and Delicious apples with qualities equivalent to those used in these tests could be prepackaged in bags at harvest and stored for 2 months at 32° F. in corrugated shipping cartons without any repacking problem. However, if stored for 3 months at 32°, 33 percent of the bags of Jonathan apples and 8 percent of the bags of Delicious apples might require repacking. Storage at 40° increased spoilage and thus would increase the repacking problem.

Table 11.–Percentage of bags requiring repacking after storage[1]

Variety and storage temperature	Months stored		
	1	2	3
	Percent	Percent	Percent
Jonathan:			
32° F.	0	0	33
40° F.	8	8	42
Delicious:			
32° F.	0	0	8
40° F.	0	17	17

[1] Mean of three orchards. Percentage of bags containing one or more apples with decay or internal breakdown.

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